

FRAGMENTATION OF VERY HIGH ENERGY HEAVY IONS

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A stack of CR39 ($C_{12}H_{18}O_7$)_n nuclear track detectors with a Cu target was exposed to a 158 A GeV lead ion beam at the CERN-SPS, in order to study the fragmentation properties of lead nuclei. Measurements of the total, break-up and pick-up charge-changing cross sections of ultrarelativistic Pb ions on Cu and CR39 targets are presented and discussed.

1 Introduction

We present experimental results on fragmentation charge-changing cross sections of 158 A GeV lead ions (charge $Z = 82e$) incident on Cu and CR39 targets. To detect and identify the relativistic ions, the nuclear track detector CR39 was used. When an ion crosses a nuclear track detector foil, it produces damages at the level of molecular bonds, forming the so called “latent track”. During the chemical etching of the detector in a basic water solution, etch-pit cones are formed on both sides of the foil. The base area and the height of each cone are functions of the Restricted Energy Loss (REL) of the incident ion and thus of its charge Z ^{1,2}.

2 Experimental procedure

A stack made of CR39 nuclear track detectors with a Cu target was exposed in November 1996 at the CERN-SPS to a beam of 158 A GeV Pb ions. The exposure was performed at normal incidence. The total number of lead ions incident on the stack was about 7.8×10^4 , distributed in 8 spots. The central density in each spot was around 1500 ions/cm².

The stack had the following composition: 12 CR39 sheets ~ 0.6 mm thick, a Cu target ~ 10 mm thick; 38 CR39 sheets ~ 0.6 mm thick. In the present

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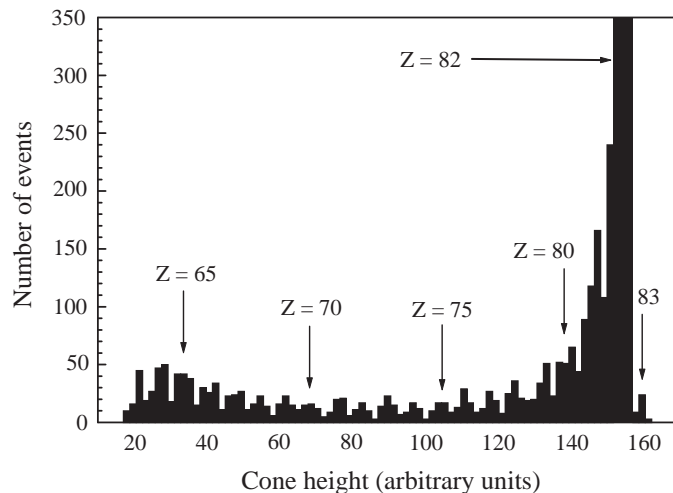


Figure 1: Cone height distribution for Pb ions and heavy fragments measured on one face of the CR39 sheet immediately after the Cu target.

analysis, the CR39 sheets immediately before and after the Cu target and the last sheet of the stack were used. After exposure, the sheets were etched for 72 h in a 4N KOH water solution at a temperature of 45 °C. Previous calibrations of the detectors have shown that for high Z nuclei, the height of the etched cone is more sensitive to Z than its base area or diameter³. In order to separate the lead ions from the nuclear fragments with charge $Z \geq 63e$, we performed manual measurements of about 6300 cone heights using an optical Zeiss microscope with a magnification of 40 \times . Fig. 1 shows the cone height distribution of Pb ions and heavy fragments measured on a single face of the CR39 sheet located after the Cu target. The charge resolution obtained is about $0.2e$.

3 Total charge-changing cross sections

Using the survival fraction of lead ions for the Cu and CR39 targets, we measured the total charge-changing cross sections of lead ions using the formula:

$$\sigma_{tot} = \frac{A_T}{\rho_T t_T N_A} \ln \frac{N_{in}}{N_{out}} \quad (1)$$

where N_{in} and N_{out} are the numbers of lead ions before and after the target, respectively; N_A is Avogadro's number; ρ_T , A_T , t_T are the density, the atomic

mass and the thickness of the target. The data are indicated by the black points in Fig. 2, the uncertainties are statistical only.

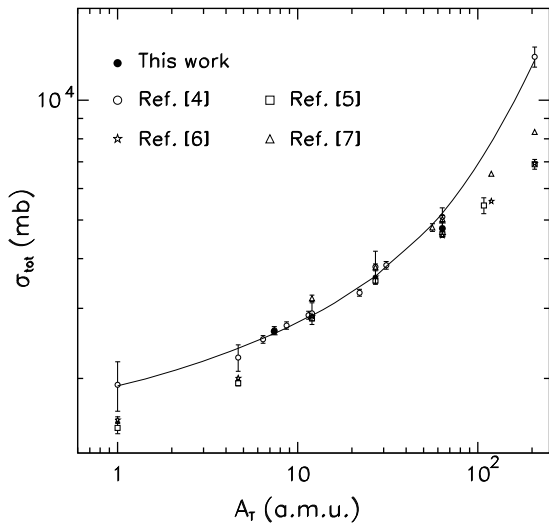


Figure 2: Measured total fragmentation charge-changing cross sections σ_{tot} of 158 A GeV Pb projectiles versus the target mass number A_T : the black points are our data on Cu and CR39, the open points refer to data obtained by a similar experiment⁴ using the same beam. The solid line represents the fit of all the data to formula (2) of ref. [4]. Results from a 10 A GeV Au beam incident on various targets [5–7] are also shown.

As shown in Fig. 2, the data are in agreement with previous data obtained by a similar experiment using the same beam and different targets with atomic masses ranging from 4.7 a.m.u. (CH_2) to 207 a.m.u. (Pb)⁴. The solid line in Fig. 2 is the fit of all the data to formula (2) of ref. [4] which yields $\chi^2/D.o.F. = 0.7$. Results from other experiments using a 10 A GeV Au beam incident on various targets [5–7] are also shown in Fig. 2.

4 Partial fragmentation charge-changing cross sections

The partial fragmentation charge-changing cross sections of Pb ions yielding fragments with charge $64e \leq Z < 82e$ were calculated for the Cu and CR39 targets using the formula⁸:

$$\sigma_Z = \frac{A_T}{\rho_T t_T N_A} \frac{N_Z}{N_{82}} \quad (2)$$

where $Z = 64e \div 81e$, N_Z is the number of fragment nuclei with charge Z produced in the target, N_{82} is the number of unfragmented beam nuclei and ρ_T , A_T , t_T , N_A have the same meaning as in Eq. (1). In this procedure, the successive fragmentation processes are neglected. The results for the partial fragmentation cross sections of incident lead ions on Cu and CR39 targets are shown versus ΔZ in Fig. 3.

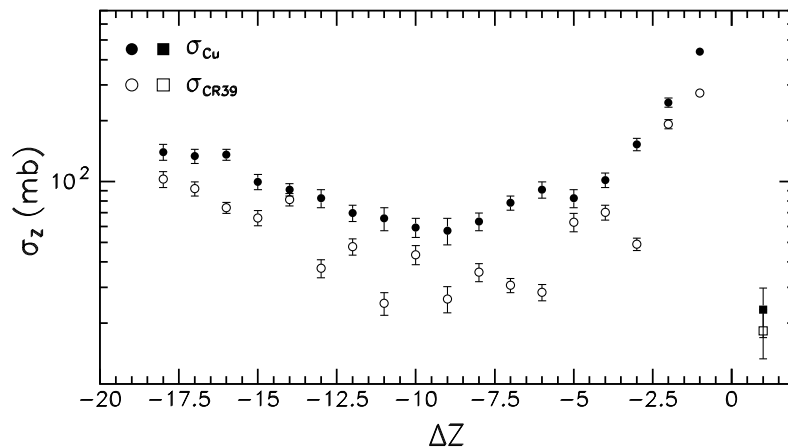


Figure 3: Partial fragmentation charge-changing cross sections for incident lead ions, σ_Z versus ΔZ for the Cu and CR39 targets computed with Eq. (2). The black points refer to σ_Z for Cu, the open points refer to σ_Z for CR39. The squares refer to the pick-up cross sections. The errors are only statistical.

The square points in Fig. 3 refer to the charge pick-up cross sections, determined using Eq. (2) where N_Z is the number of nuclei with $Z = 83e$ produced in the target.

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